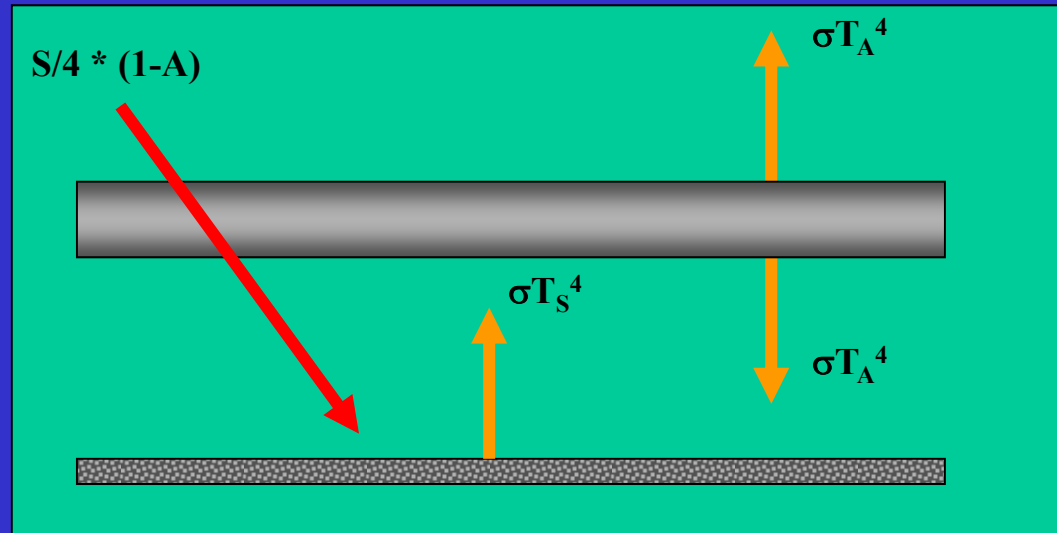


Lecture 5: Greenhouse Effect



- ☐ Wien's Law
- ☐ Shortwave and Longwave Radiation
- ☐ Selected Absorption → Greenhouse Effect

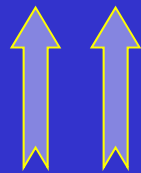


VISIT...

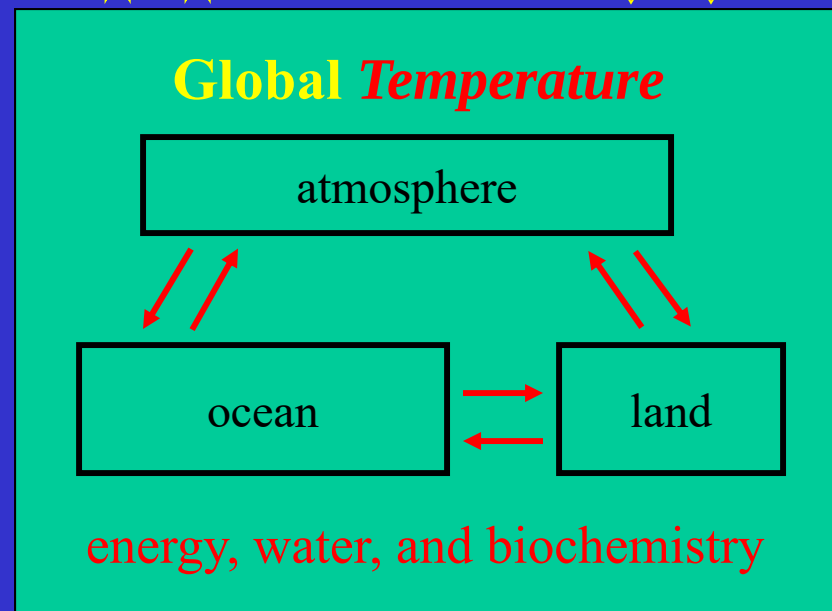
LANZAROTE
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Global *Energy* Balance

terrestrial radiation cooling



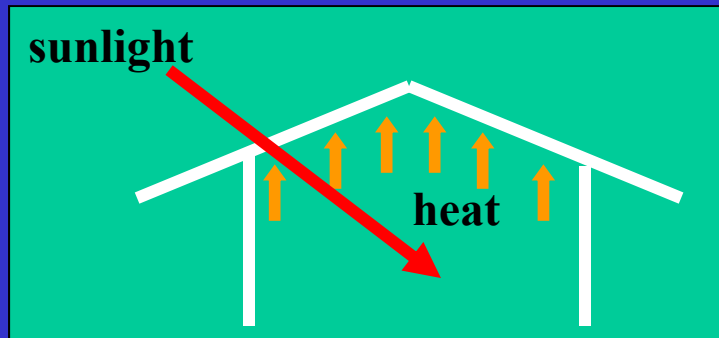
Solar radiation warming



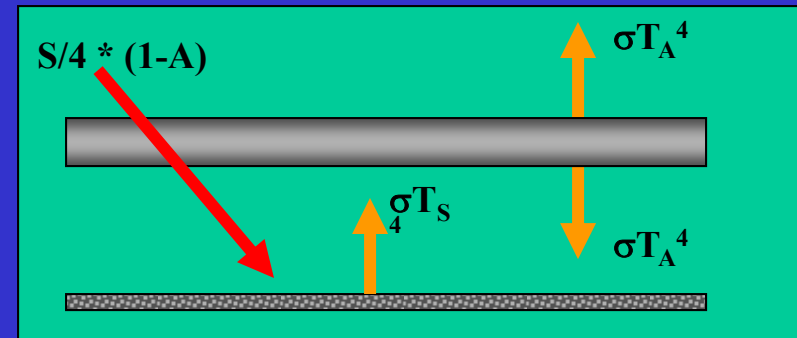


Why Is It Called “Greenhouse Effect”?

Greenhouse



Atmosphere



- allow sunlight to come in
- trap heat in the atmosphere (house)



Two Key Reasons for the Greenhouse Effect

- ❑ Solar and terrestrial radiations are emitted at very different wavelengths.
- ❑ The greenhouse gases selectively absorb certain frequencies of radiation.



Spectrum of Radiation

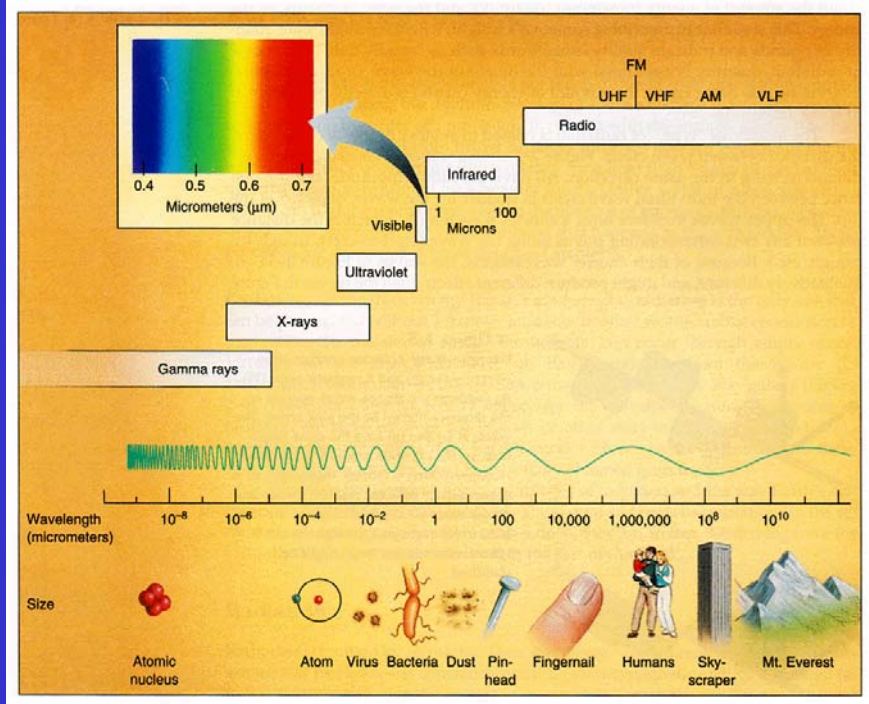


Table 2-1 Wavelength Categorizations

Type of Energy	Wavelength (micrometers)
Gamma	<0.0001
X ray	0.0001 to 0.01
Ultraviolet	0.01 to 0.4
Visible	0.4 to 0.7
Near Infrared (NIR)	0.7 to 4.0
Thermal Infrared	4 to 100
Microwave	100 to 1,000,000 (1 meter)
Radio	>1,000,000 (1 meter)

(from *Understanding Weather & Climate*)

- ❑ Radiation energy comes in an infinite number of wavelengths.
- ❑ We can divide these wavelengths into a few bands.



Micrometer (μm)

1 micrometer (μm) = 10^{-6} meter (m)



Blackbody Radiation

❑ Blackbody

A blackbody is something that emits (or absorbs) electromagnetic radiation with 100% efficiency at all wavelength.

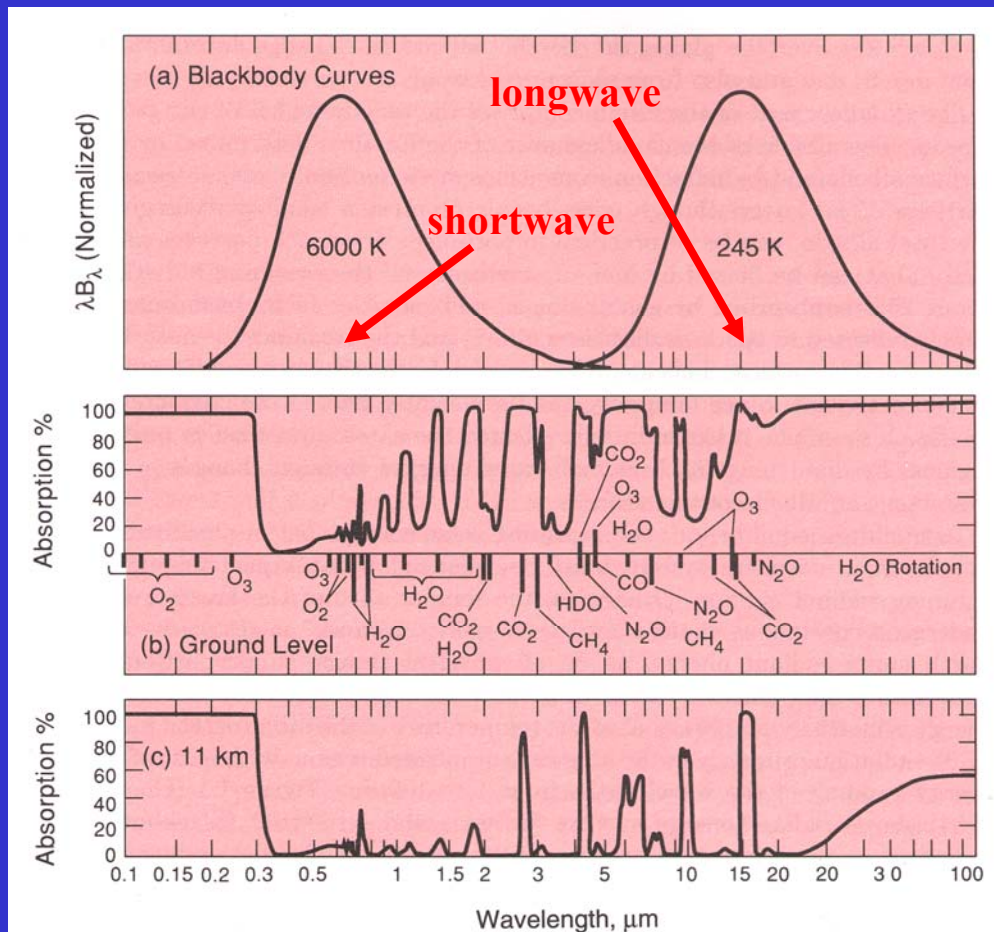
❑ Blackbody Radiation

The amount of the radiation emitted by a blackbody depends on the absolute temperature of the blackbody.



Different Wavelengths of Solar and Earth's Radiation

Normalized Planck Function



(from *Climate System Modeling*)

Planck Function

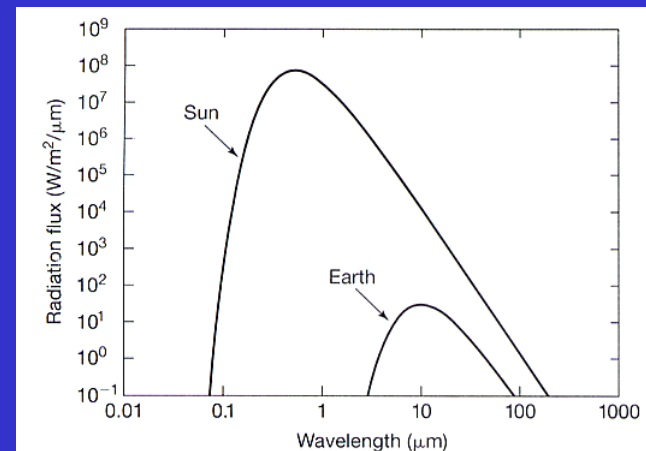


FIGURE 3-8

Blackbody emission curves for the Sun and Earth. The Sun emits more energy at all wavelengths.

(from *The Earth System*)



Stefan-Boltzmann Law

$$E = \sigma T^4$$

E = radiation emitted in W/m²

$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K} \cdot \text{sec}$

T = temperate (K *← Kelvin degree*)

- ❑ The single factor that determine how much energy is emitted by a blackbody is its temperature.
- ❑ The intensity of energy radiated by a blackbody increases according to the fourth power of its absolute temperature.
- ❑ This relationship is called the Stefan-Boltzmann Law.



Wien's Law

$$\lambda_{max} = W/T$$

λ_{max} = wavelength (micrometers)

$W = 2897 \mu\text{m K}$

T = temperate (K)

- ❑ Wien's law relates an objective's maximum emitted wavelength of radiation to the objective's temperature.
- ❑ It states that the wavelength of the maximum emitted radiation by an object is inversely proportional to the objective's absolute temperature.



Apply Wien's Law To Sun and Earth

☐ Sun

$$\begin{aligned}\lambda_{\max} &= 2898 \mu\text{m K} / 6000\text{K} \\ &= 0.483 \mu\text{m}\end{aligned}$$

☐ Earth

$$\begin{aligned}\lambda_{\max} &= 2898 \mu\text{m K} / 300\text{K} \\ &= 9.66 \mu\text{m}\end{aligned}$$

- ☐ Sun radiates its maximum energy within the visible portion of the radiation spectrum, while Earth radiates its maximum energy in the infrared portion of the spectrum.



Spectrum of Radiation

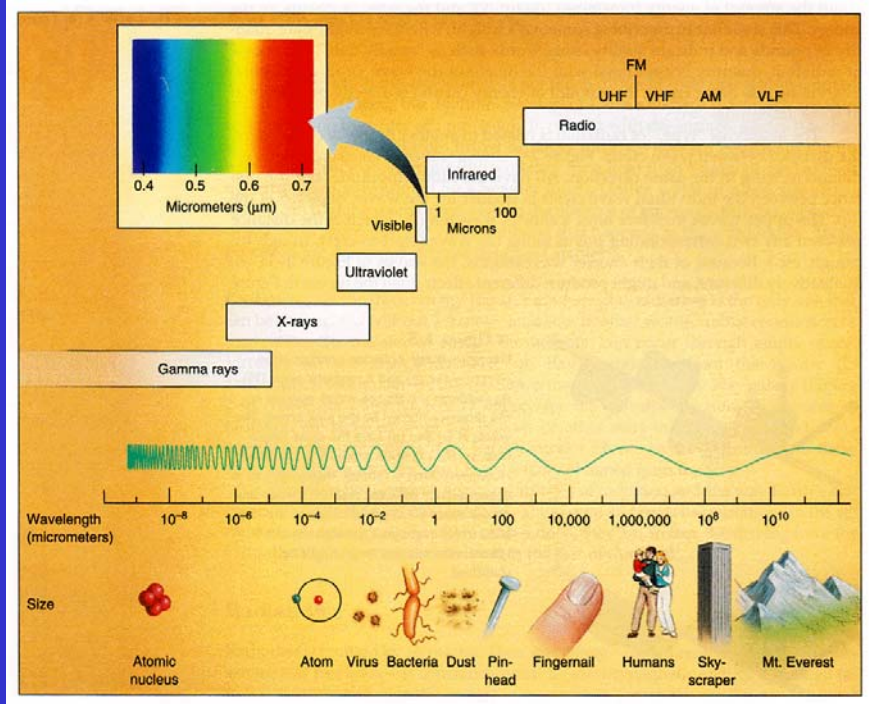


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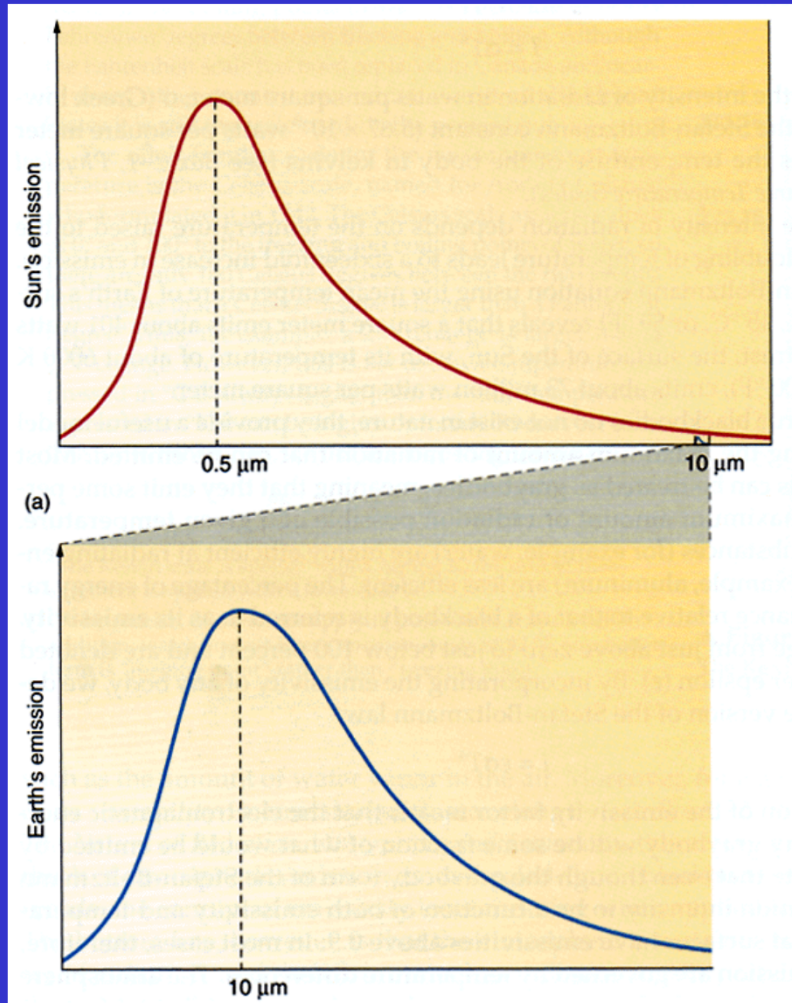
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(from *Understanding Weather & Climate*)

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- ❑ We can divide these wavelengths into a few bands.



Solar and Terrestrial Radiation

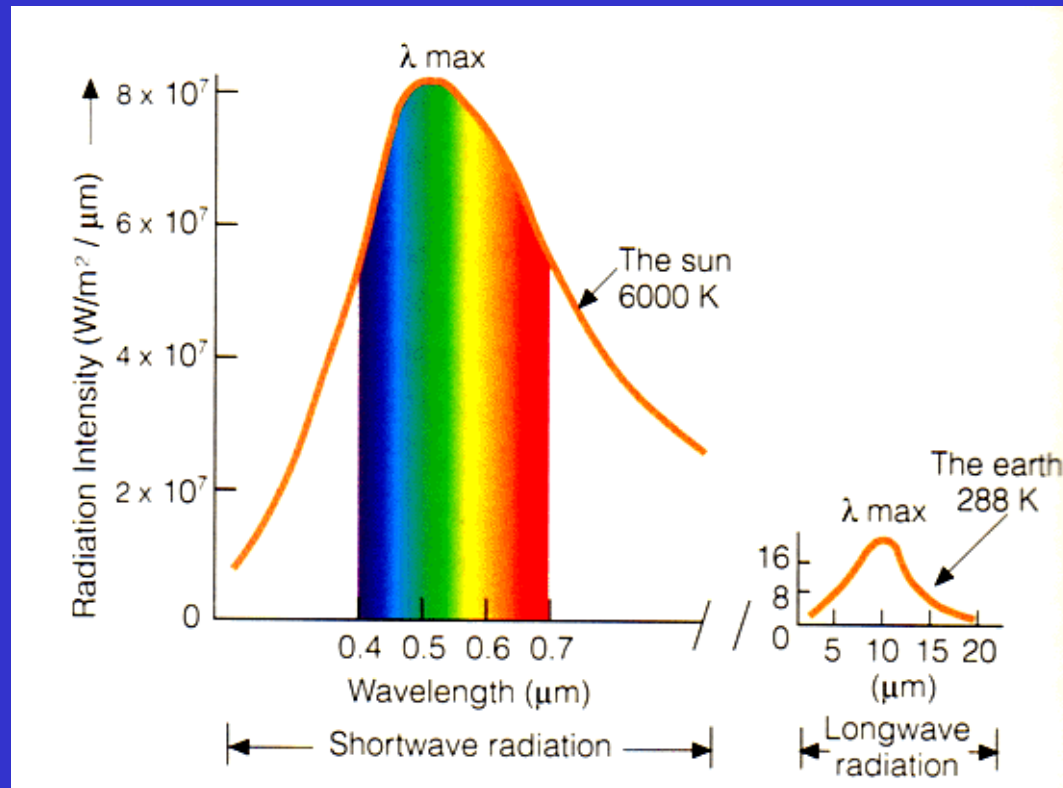


(from *Understanding Weather & Climate*)

- ☐ All objects radiate energy, not merely at one single wavelength but over a wide range of different wavelengths.
- ☐ The sun radiates more energy than the Earth.
- ☐ The greatest intensity of solar energy is radiated at a wavelength much shorter than that of the greatest energy emitted by the Earth.



Shortwave and Longwave Radiations



(from *Meteorology: Understanding the Atmosphere*)

- ❑ Solar radiation is often referred to as “shortwave radiation”.
- ❑ Terrestrial radiation is referred to as “longwave radiation”.



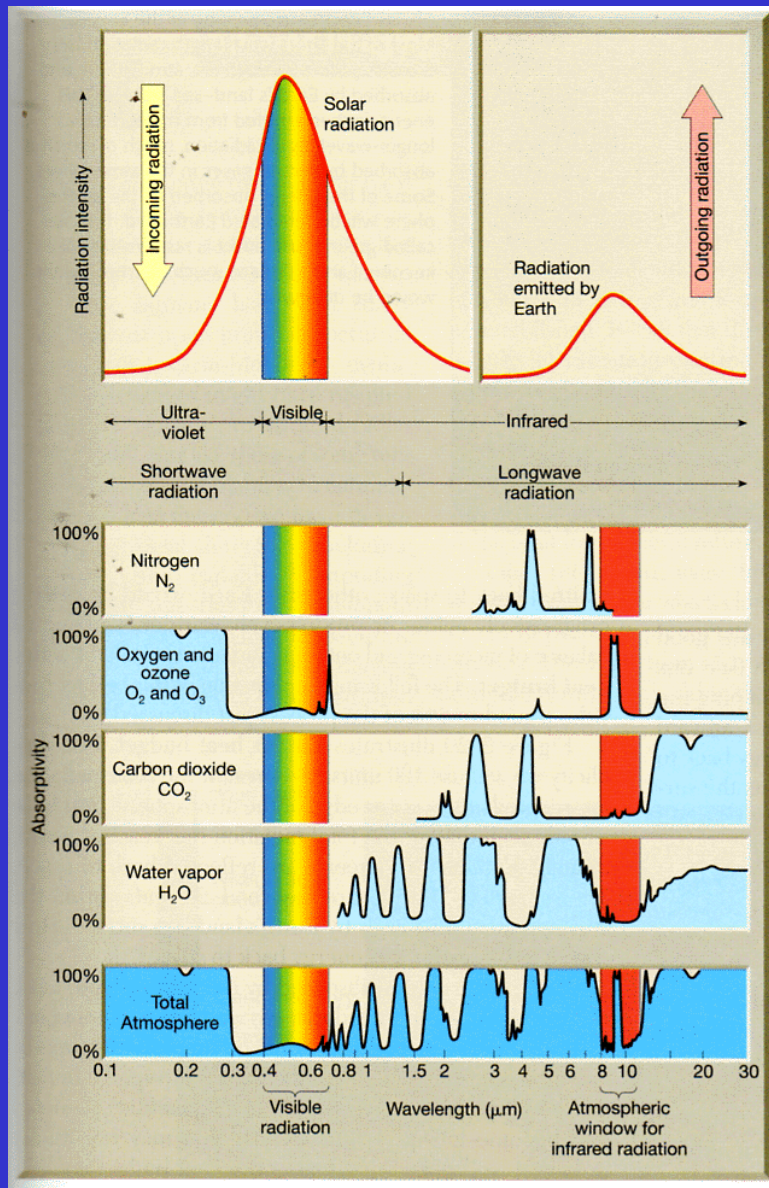
Two Key Reasons for the Greenhouse Effect

❑ Solar and terrestrial radiations are emitted at very different wavelengths.

❑ The greenhouse gases selectively absorb certain frequencies of radiation.



Selective Absorption and Emission



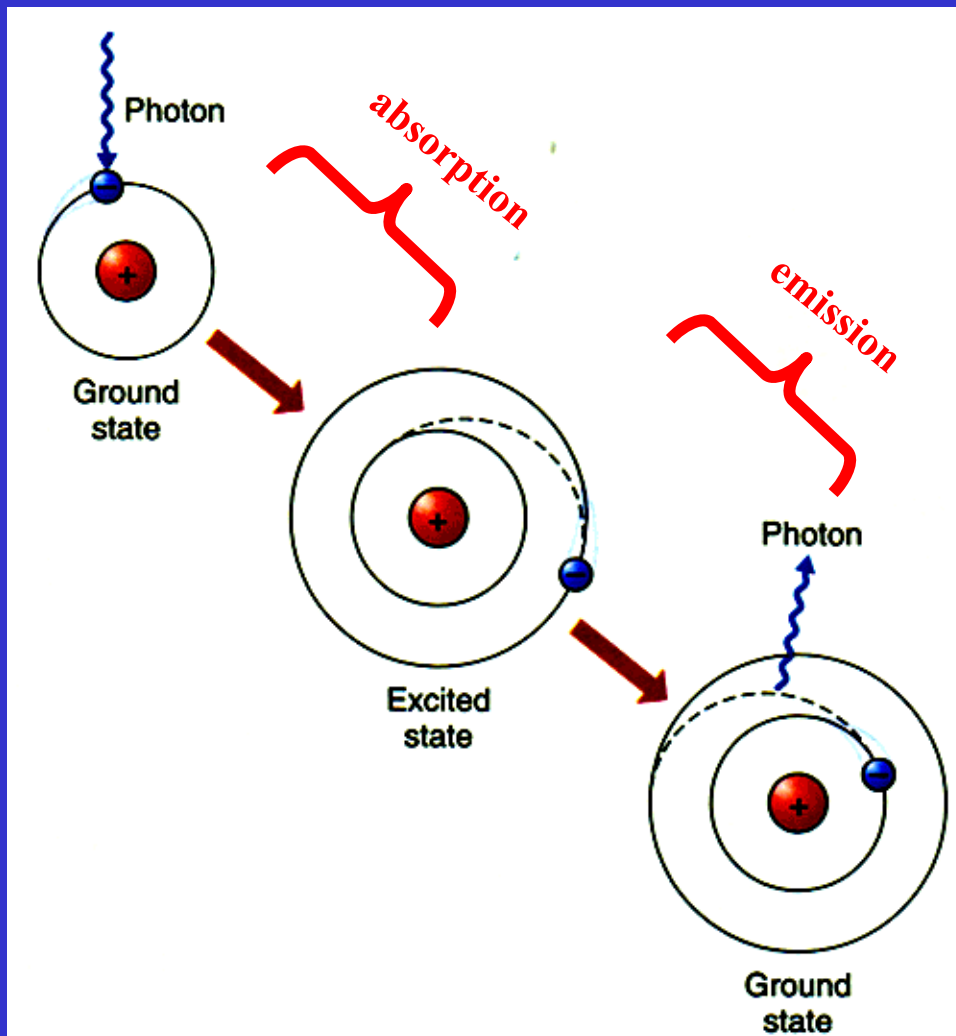
- ❑ The atmosphere is not a perfect blackbody, it absorbs some wavelength of radiation and is transparent to others (such as solar radiation). → Greenhouse effect.
- ❑ Objective that selectively absorbs radiation usually selectively emit radiation at the same wavelength.
- ❑ For example, water vapor and CO₂ are strong absorbers of infrared radiation and poor absorbers of visible solar radiation.

(from *The Atmosphere*)



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Prof. Jin-Yi Yu

Why Selective Absorption/Emission?

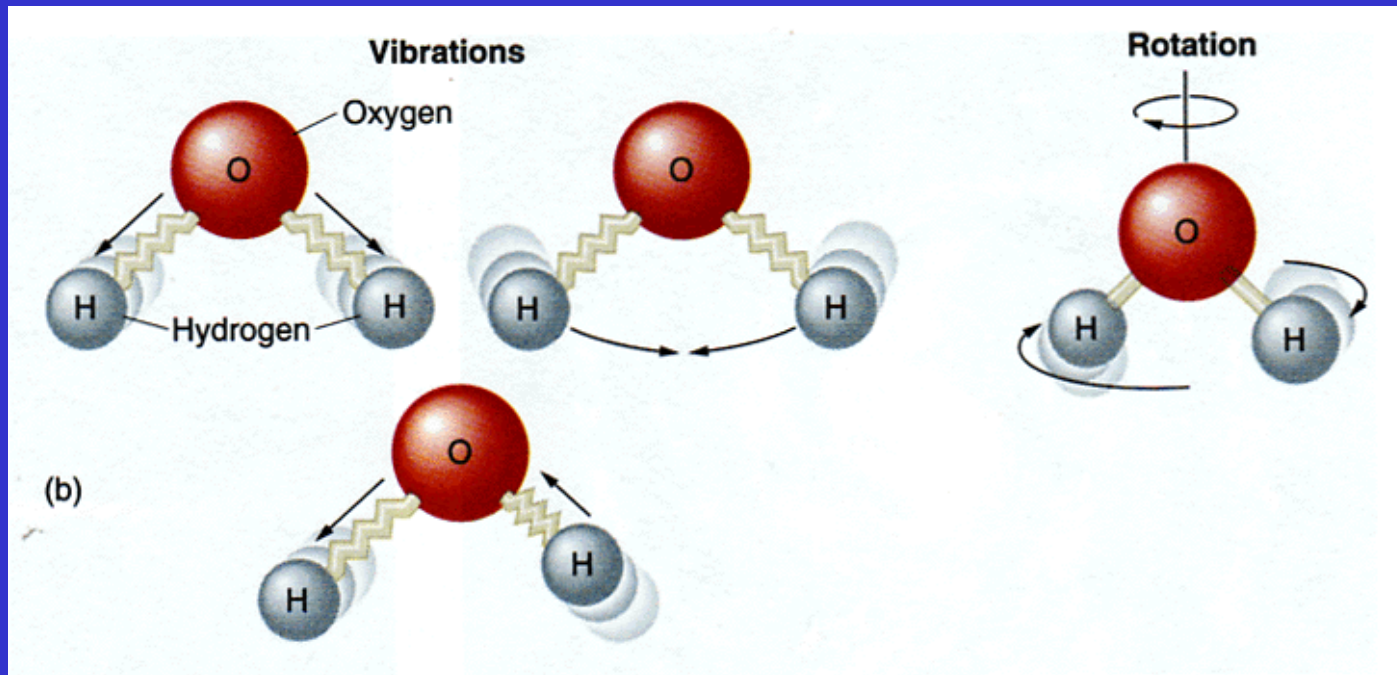


(from *Understanding Weather & Climate*)

- ❑ Radiation energy is absorbed or emitted to change the energy levels of atoms or molecular.
 - ❑ The energy levels of atoms and molecular are discrete but not continuous.
 - ❑ Therefore, atoms and molecular can absorb or emit certain amounts of energy that correspond to the differences between the differences of their energy levels.
- ➔ Absorb or emit at selective frequencies.



Different Forms of Energy Levels

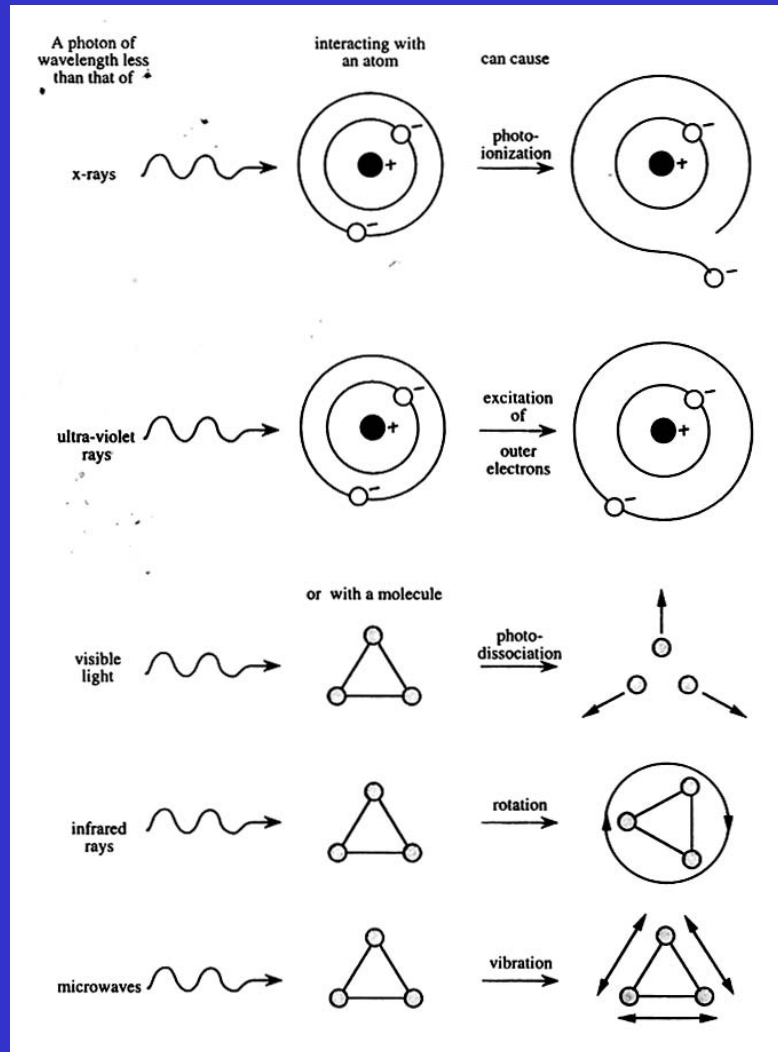


(from *Understanding Weather & Climate*)

- ❑ The energy of a molecule can be stored in (1) translational (the gross movement of molecules or atoms through space), (2) vibrational, (3) rotational, and (4) electronic (energy related to the orbit) forms.



Energy Required to Change the Levels



□ The most energetic photons (with shortest wavelength) are at the top of the figure, toward the bottom, energy level decreases, and wavelengths increase.

(from *Is The Temperature Rising?*)

